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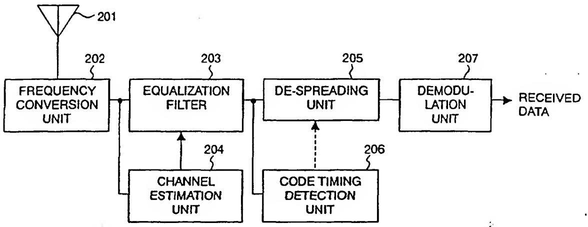
(54) MOBILE STATION RECEIVING METHOD AND MOBILE STATION RECEIVER

(57) An object of the present invention is to prevent degradation of communication quality and decrease of manageable number of mobile terminals due to interference by signal components received at different timings under channel distortion. The present invention is directed to a mobile station receiving method on a down channel in a CDMA (Code Division Multiple Access) cellular system in which a base station modulates, by using orthogonal pseudo noise sequences, transmission signals towards a plurality of mobile stations, transmits the modulated signals synchronously, while the mobile stations receive the modulated signals distorted by a plurality of radio channels of which delay times are different. The modulated signals transmitted by the base station are equalized and demodulated by using a filter of which frequency characteristics is inverse to that of the radio channels.

Fig. 1



EP 1 128 569 A1

Description

Technical Field

[0001] The present invention relates to a mobile station receiving method and receiver for a mobile station and a communication system on a down channel in a CDMA (Code Division Multiple Access) cellular system, wherein a plurality of signals modulated by pseudo noise sequences which are orthogonal with each other.

Background Art

[0002] In the down channel of the code division multiple access cellular mobile communication system (CDMA cellular), the transmission signals to the terminals are modulated by the orthogonal pseudo noise sequences which are synchronized with each other.

[0003] The interference between the codes is reduced by using the synchronized orthogonal codes, thereby obtaining a high communication capacity. The mobile terminal filters the received signal by using a matching filter which is provided with tap coefficients which correspond to the pseudo noise sequences allocated to the mobile terminal, in order to select the signal directed to the mobile terminal. The output from the matching filter becomes great, when the correlation between the pseudo noise sequences indicated by the tap coefficients and the received signal.

[0004] The signal transmitted from the base station is distorted through a plurality of propagation paths. Therefore, the mobile station receives a plurality of delayed signal components. Accordingly, the waveform outputted from the matching filter contains a plurality of peaks affected by propagation losses and delays. The mobile station can make good use of the received signal, if the mobile station demodulates the plurality of the peaks independently and combines them. The RAKE receiving method is indispensable for the CDMA cellular, because it utilizes effectively the plurality of signal components dispersed by the plurality of delay times. The RAKE receiving is, for example, described in Proceedings of the IRE, pp.555-570, March, 1958.

[0005] Figure 5 is an example of a conventional mobile receiver provided with the RAKE receiving unit. The signal received by antenna 101 is converted into a base band signal by frequency conversion unit 102. The output from frequency conversion unit 102 is outputted toward code timing detection unit 106 in order to measure demodulation timings and received signal intensities of signal components of a plurality of delay times. The output from frequency conversion unit 102 which contains the signal components of the plurality of delay times is also inputted into despreading unit 103 ~ 105 in order to despreading the signal, on the basis of the demodulation timings and the received signal intensities which are detected by code timing detection unit 106.

[0006] Further, the outputs from de-spreading units 103 to 105 are inputted into decoders 107 to 109 in order to decode the signal components. The decoded signal components are combined by combining unit 110 in order to output received data.

[0007] Figure 6 is an example of a received waveform measured by code timing detection unit 106. The horizontal axis represents time and the vertical axis represents signal intensity. The waveform "a" and "b" are the signal components which are received at different timings. The two signal components through different propagation paths are shown separately for simplicity in Figure 6, although they are superimposed in the waveform actually received. As shown in Figure 6, the received waveform has a plurality of peaks due to distortions by propagation paths. Code timing detection unit 106 detects the peak positions and the peak intensities.

[0008] The communication quality of the mobile station is decided only by interference from other cells and noise, because any interference does not occur in principle in a cell on distortion-free down channel, when the orthogonal synchronous codes are used by the CDMA transmitter. However, an effect of channel distortion is actually inevitable, because signals are spread in wide band in the CDMA.

[0009] Due to interference caused by the channel distortion, signal components of deferent decoding timings are received. Figure 7 is an example of the waveform measured by code timing detection unit 106, when a plurality of undesired signals such as signals directed to other terminals are included. For simplicity, signal components from deferent propagation paths are separately indicated, as well as the desired signal and undesired signal.

[0010] The actual waveform is a superposition of every waveform as shown in Figure 7. Desired signal d-1 is received simultaneously with undesired signal i-1, while desired signal d-2 is received simultaneously with undesired signal i-2. Sampling points s-1 and s-2 are the points were desired signals d-1 and d-2 become maximums. If the receiving timing of the desired signal is the same as that of the undesired signal, undesired signals i-1 and i-2 become zero at sampling points s-1 and s-2., due to the adoption of the orthogonal synchronous codes. On the contrary, if the receiving timings are deferent, non-desires signals i-1 and i-2 are received as an interference signal. The interference increases as the mobile stations connected with the base station increase. As a result, the communication qualities are degraded and the number of the mobile stations must unavoidably be reduced.

[0011] Therefore, an object of the present invention is to suppress the interference due to the channel distortion in the CDMA cellular system, wherein desired signals and undesired signals are spread by the orthogonal pseudo noise sequences.

Disclosure of the Invention

[0012] In the signal receiving method and apparatus for mobile station of the present invention in the CDMA cellular system using the synchronous orthogonal codes on the down channel, the mobile receiver or a down channel receiver includes an equalizer for equalizing the channel distortion.

[0013] On the down channel of the code division multiple access cellular mobile communication system (CDMA cellular), the signals transmitted to the mobile terminals are spectrum-spread signals by the orthogonal codes which are synchronized with each other. The signals transmitted by the base station are received by the mobile terminals through a plurality of propagation paths which causes the channel distortions which cause a plurality of signal components with a plurality of delay times. The signal components at different decoding timings are received as interference. The equalizer equalizes the channel distortions before decoding the received signals.

[0014] The present invention is directed to the down channel in the CDMA cellular communication system, wherein the base station makes up a plurality of spectrum-spread signals by using the orthogonal codes, and transmits them by superposing them in the synchronized state, while the plurality of mobile stations receives them which are distorted by a plurality of radio channels with different delay times. In this communication system, the mobile station comprises a frequency conversion unit for converting the signal receive by an antenna into a base band signal, a propagation channel estimation unit for detecting a frequency characteristic of the radio channel on the basis of the uotput from the frequency conversion unit, a filter unit for generating the inverse characteristic of the radio channel, and a decoding unit for decoding the output from the filter unit.

[0015] According to the present invention, the interference due to the channel distortion is eliminated, because the delay is eliminated by the equalization of the frequency characteristic by generating the inverse frequency characteristic. Accordingly, the communication quality becomes high and the communication capacity becomes large, due to the elimination of the interference.

[0016] The distortion of the desired signal from the connected base station is the same as that of the interference signal, because the propagation paths of the desired signal is the same as that of the interference signal. Therefore, the interference is eliminated by equalizing the channel distortion suffered by the signal received by the mobile station.

Brief Explanation of the Drawings

[0017] Figure 1 shows an embodiment of the mobile terminal of the present invention.

[0018] Figure 2 is a waveform outputted from the equalizing filter.

[0019] Figure 3 is a graph of received DUR vs. the number of users of the mobile terminals.

[0020] Figure 4 shows another embodiment of the mobile terminal of the present invention.

[0021] Figure 5 shows a conventional mobile terminal.

[0022] Figure 6 is a waveform outputted from a matching filter of the conventional mobile terminal.

[0023] Figure 7 a waveform outputted from a matching filter of the conventional mobile terminal, when interference exists.

[0024] Figure 8 is a block diagram of the equalizing filter used by the mobile terminal of the present invention.

[0025] Figure 9 is a block diagram of the channel estimation unit used by the mobile terminal of the present invention.

Best Mode for Carrying Out the Invention

[0026] The best mode for carrying out the present invention is explained, with reference to the drawings.

[First Embodiment]

(Construction of the first embodiment)

[0027] The first embodiment of the present invention is shown in Figure 1. In Figure 1, the signal received by antenna 201 is inputted into frequency conversion unit 202 which may be of direct system for converting directly the received signal into a base band signal, or may be of super heterodyne for converting the received signal into a base band signal through a radio frequency amplification stage, an intermediate frequency amplification stage and a detection stage. The output from frequency conversion unit 202 is inputted simultaneously into both of equalizing filter 203 and channel estimation unit 204. The transfer function F(f)of equalizing filter 203 is made to be the inverse of the transfer function C(f) of the propagation channel which are estimated by channel estimation unit 204.

[0028] Therefore,

$$F(f) = 1/C(f) \qquad (1)$$

,where "f" is frequency.

[0029] Next, the output from equalizing filter is inputted simultaneously into both of de-spreading unit 205 and code timing detection unit 206. Code timing detection unit 206 measures the decoded timing of the signal component of which distortion is eliminated by equalizing filter 203, while de-spreading unit 205 de-spreads the signal component at the decoded timing. The de-spread signal is inputted into decoding unit 207 in order to output the received data.

[0030] Figures 8 and 9 show embodiments of equalizing filter 203 and channel estimation unit 204, respectively. Equalizing filter 203 as shown in Figure 8 is a feed forward filter with "n" raps. As shown in Figure 8, the base band signal outputted from frequency conversion unit 202 goes through delay circuits T2031 to 2033 which are connected in series. The outputs from delay circuits are multiplied by tap weight coefficients W1 to W3, respectively, and then added in adder 2038. The output fron adder 2038 is outputted toward de-spreading unit 205 and code timing detection unit 206.

[0031] The base band signal outputted from frequency conversion unit 202 is also inputted into channel estimation unit 204 as shown in Figure 9. The base band signal includes a pilot signal which is a spectrum spread signal with a prescribed pseudo noise sequence. Matching filter 2041 is matched to the pilot signal. Therefore, an impulse response is obtained by inputting the base band signal into matching filter 2041. The output from matching filter 2041 is inputted into weight coefficients decision unit 2042 in order to decide tap weight coefficients W1 to Wn in equalizing filter 2041 as shown in Figure 8. Here, the tap weight coefficients W1 to Wn are decided in such a manner that the characteristics of equalizing filter is inverse of the impulse response of the channel. Weight coefficients decision unit 2042 outputs the decided tap weight coefficients W1 to Wn toward equalizing filter 203.

[0032] Although a single de-spreading unit 205 and a single decoding unit 207 are shown in Figure 1, RAKE receiving system which contains a plurality of de-spreading units and combining the results of de-spreading may be adopted in order to improve a data error rate.

(Explanation of the Operation of the Embodiment)

[0033] Figure 2 shows an example of a received waveform measured by timing detection unit 206 in the receiving system for mobile station of the present invention. The desired signal is waveform d-3, while the undesired signal is waveform i-3.

[0034] In Figure 2, the desired signal is separated from the undesired signal, for easy understanding, although the waveform actually received is a superposition od the two wave forms. The output from the matching filter contains interference due to the undesired signal components at the sample points as shown in Figure 7, under the channel distortion.

[0035] However, The interference disappear at the sample points where the received signal become maximum, because the channel distortion is equalized as shown in Figure 2 in the receiving system for mobile station of the present invention. Figure 3 shows the DUR (Desired to Undesired signal power Ratio) of the conventional system as shown in Figure 5 and the DUR of the system of the present invention as shown in Figure 1.

[0036] In Figure 3, curve 1-c is the DUR of the conventional system, while curve 1-p is the DUR of the system of the present invention. The DUR as shown by curve 1-c decreases as the mobile stations increase, while the DUR as shown by curve 1-p stays constant regardless of the number of mobile stations. On the other hand, when the number of mobile stations decreases, the DUR as shown by curve 1-c becomes greater than the DUR of the system of the present invention, due to the effect of the RAKE receiving. In conclusion, The communication quality of the present invention becomes better than that of the conventional system, due to the elimination of interference by the equalization, when a lot of mobile stations is controlled by a base station.

[0037] Therefore, a single base station can controls greater number of mobile stations in the present invention than in the conventional system.

[Second Embodiment]

[0038] The second embodiment of the present invention is shown in Figure 4. As shown in Figure 4, the signal received by antenna 301 is converted into a base band signal by frequency conversion unit 302 of which output is inputted into RAKE receiver 303 and equalizing receiver 304.

[0039] RAKE receiver 303 may be the conventional RAKE receiver as shown in Figure 5, while equalizing receiver may be the equalizing receiver as shown in Figure 1. The outputs from RAKE receiver 303 and equalizing receiver 304 are inputted into selector 305 in order to output higher quality data.

[0040] In the second embodiment as shown in Figure 4, the output from RAKE receiver is compared with the output from equalizing receiver, in order to select the higher quality signal. As shown in Figure 3, the signal quality becomes lower, when the signal is decoded only by the equalizing under the smaller number of mobile stations controlled by a base station. However, according to the second embodiment, the signal quality is high due to the effect of RAKE receiving, even when the number of mobile stations is small.

<u>Industrial Applicability</u>

[0041] According to the present invention, the interference due to the undesired signal of which timing is different from that of the desired signal is eliminated by the equalization of channel distortion. Therefore, the communication quality becomes high and the down channel capacity becomes large, due to the interference elimination.

Claims

1. A mobile station receiving method on a down channel in a CDMA (Code Division Multiple Access) cel-

lular system in which a base station modulates, by using orthogonal pseudo noise sequences, transmission signals towards a plurality of mobile stations, transmits the modulated signals synchronously, while said mobile stations receive the modulated signals distorted by a plurality of radio channels of which delay times are different,
which is **characterized in that** the modulated signals transmitted by said base station are equalized and demodulated by using a filter of which frequency characteristics is inverse to that of said radio channels.

2. The mobile station receiving method according to claim 1, wherein said filter comprises:

a plurality of delay circuits which are connected in series;
a plurality of multipliers each of which multiples each prescribed weight coefficient by the output from each delay circuit; and
an adder for adding the outputs from said multipliers,
wherein said modulated signals are equalized adaptively as the distortions of said radio channels changes.

3. A mobile station receiving method on a down channel in a CDMA (Code Division Multiple Access) cellular system in which a base station modulates, by using orthogonal pseudo noise sequences, transmission signals towards a plurality of mobile stations, transmits the modulated signals synchronously, while said mobile stations receive the modulated signals distorted by a plurality of radio channels of which delay times are different,
which comprises:

a first method for equalizing and demodulating said modulated signals from said base station, by using a filter of which frequency characteristics is inverse with that of said radio channels; and
a second method for demodulating independently each of said modulated signals which pass through a plurality of said radio channels of which delay times are different, and for combining the demodulation results,
which is **characterized in that** an output with higher communication quality is selected among the outputs by said first and second method.

4. The mobile station receiving method according to claim 3, wherein said filter comprises:

a plurality of delay circuits which are connected in series;
a plurality of multipliers each of which multiples each prescribed weight coefficient by the output from each delay circuit; and
an adder for adding the outputs from said multipliers,
wherein said modulated signals are equalized adaptively as the distortions of said radio channels changes.

5. A mobile station receiving method on a down channel in a CDMA (Code Division Multiple Access) cellular system in which a base station modulates, by using orthogonal pseudo noise sequences, transmission signals towards a plurality of mobile stations, transmits the modulated signals synchronously, while said mobile stations receive the modulated signals distorted by a plurality of radio channels of which delay times are different, which is **characterized in that** said mobile station comprises:

a frequency conversion unit for converting said modulated signals received by an antenna into base band signals;
a channel estimation unit for detecting frequency characteristics of said radio channels on the basis of said modulated signals;
a filter unit of which frequency characteristics is inverse with that of said radio channels; and
a demodulator for demodulating the outputs from said filter unit of which inputs are said base band signals.

6. A mobile station receiving apparatus on a down channel in a CDMA (Code Division Multiple Access) cellular system in which a base station modulates, by using orthogonal pseudo noise sequences, transmission signals towards a plurality of mobile stations, transmits the modulated signals synchronously, while said mobile stations receive the modulated signals distorted by a plurality of radio channels of which delay times are different, which is **characterized in that** said mobile station comprises a first receiving unit, a second receiving unit and a selection unit, wherein:

said first receiving unit comprises:

a frequency conversion unit for converting said modulated signals received by an antenna into base band signals;
a channel estimation unit for detecting frequency characteristics of said radio channels on the basis of said modulated signals;
a filter unit of which frequency characteristics is inverse with that of said radio channels; and

a demodulator for demodulating the outputs from said filter unit of which inputs are said base band signals, and

said second receiving unit comprises:

a demodulation unit for demodulating independently each of said modulated signals which pass through a plurality of said radio channels of which delay times are different; and
a combining unit for combining the demodulation results,
which is **characterized in that** said selection unit selects an output with higher communication quality is selected among the outputs by said first and second receiving units.

7. A communication system on a down channel in a CDMA (Code Division Multiple Access) cellular system in which a base station modulates, by using orthogonal pseudo noise sequences, transmission signals towards a plurality of mobile stations, transmits the modulated signals synchronously, while said mobile stations receive the modulated signals distorted by a plurality of radio channels of which delay times are different, which is **characterized in that** said mobile station comprises:

a frequency conversion unit for converting said modulated signals received by an antenna into base band signals;
a channel estimation unit for detecting frequency characteristics of said radio channels on the basis of said modulated signals;
a filter unit of which frequency characteristics is inverse with that of said radio channels; and
a demodulation unit for demodulating the outputs from said filter unit of which inputs are said base band signals.

8. A communication system on a down channel in a CDMA (Code Division Multiple Access) cellular system in which a base station modulates, by using orthogonal pseudo noise sequences, transmission signals towards a plurality of mobile stations, transmits the modulated signals synchronously, while said mobile stations receive the modulated signals distorted by a plurality of radio channels of which delay times are different, which is **characterized in that** said mobile station comprises a first receiving unit, a second receiving unit and a selection unit, wherein:

said first receiving unit comprises:

a frequency conversion unit for converting said modulated signals received by an antenna into base band signals;
a channel estimation unit for detecting frequency characteristics of said radio channels on the basis of said modulated signals;
a filter unit of which frequency characteristics is inverse with that of said radio channels; and
a demodulator for demodulating the outputs from said filter unit of which inputs are said base band signals, and

said second receiving unit comprises:

a demodulation unit for demodulating independently each of said modulated signals which pass through a plurality of said radio channels of which delay times are different; and
a combining unit for combining the demodulation results,
which is **characterized in that** said selection unit selects an output with higher communication quality is selected among the outputs by said first and second receiving units.

Fig. 1

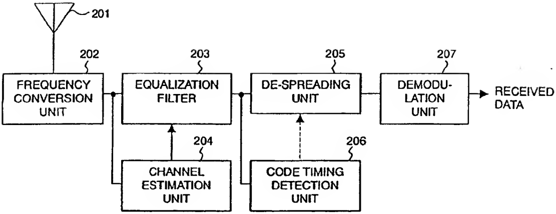


Fig. 2

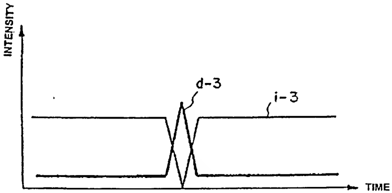


Fig. 3

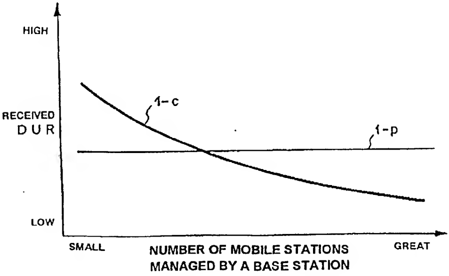


Fig. 4

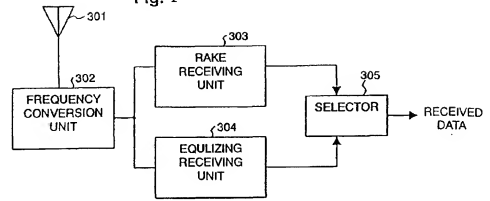


Fig. 5

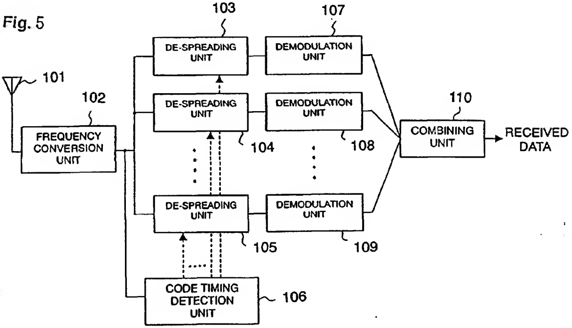


Fig. 6

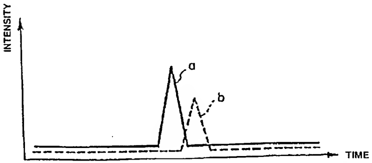


Fig. 7

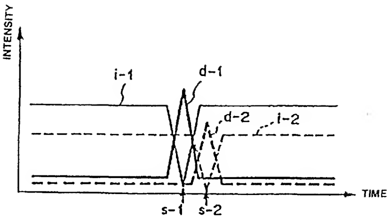


Fig. 8

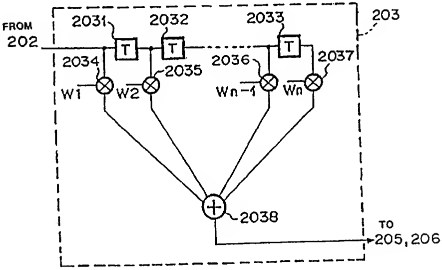
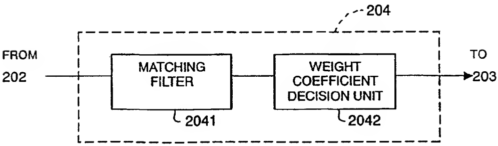


Fig. 9



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP99/05845

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl^7 H04B1/707, H04J13/00, H04B1/10, H04B7/005, H04B7/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl^7 H04B1/69-1/713, H04J13/00-13/06, H04B1/10, H04B7/005, H04B7/26

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1926-1996 Toroku Jitsuyo Shinan Koho 1994-1999
Kokai Jitsuyo Shinan Koho 1971-1999 Jitsuyo Shinan Toroku Koho 1996-1999

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	JP, 9-153843, A (NEC Corporation), 10 June, 1997 (10.06.97), page 3, column 3, line 36 to page 4, column 5, line 40; Figs. 1, 11 & US, 5903556, A	1,2,5,7 3,4,6,8
X A	JP, 10-200503, A (Matsushita Electric Ind. Co., Ltd.), 31 July, 1998 (31.07.98), page 3, column 4, line 41 to page 4, column 6, line 38; Figs. 4, 5 (Family: none)	1,2,5,7 3,4,6,8
A	JP, 10-51424, A (NTT Ido Tsushinmo K.K.), 20 February, 1998 (20.02.98) (Family: none)	1-8

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Date of the actual completion of the international search	Date of mailing of the international search report
05 January, 2000 (05.01.00)	18 January, 2000 (18.01.00)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

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